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I. CONCOMITANT ASSIMILATION OF THE ATLAS AND OCCIPUT WITH THE MANIFESTATION OF AN OCCIPITAL VERTEBRA.

II. NOTES ON A HYPOCHORDAL BRACE.

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I.

The simultaneous occurrence of fusion of the atlas and occiput, with the presence of a more or less distinct occipital vertebra, is of much importance in the discussion concerning the significance of numerical variations of the vertebral column. The observations by Zoja¹ and Swjetschnikow² both deal with the manifestation of an occipital vertebra that is most developed in its anterior and lateral portions. Although we find vague allusions in literature to the simultaneous occurrence of these two conditions, yet, so far as I know, these two anatomists are the only ones who have observed them. In point of fact it was the Russian who recognized the occipital ver-

¹Zoja, G. *Intorno all' atlante stude anthropo-zootomici. Con una tavola. Letture fatte nell' adunanze 4 marzo, 1° aprile, 13 maggio, 17 giugno 1880 e 19 maggio 1881. Pp. 269-296.*

²Swjetschnikow. *Ueber die Assimilation des Atlas und die Manifestation des Occipitalwirbels beim Menschen. Arch. für Anat. u. Physiol., Anat. Abth. 1906, pp. 155-193.*

tebra in Zoja's specimen. The case to be described in this paper differs from them in that the posterior arch of the occipital vertebra has a free point. Similar appearances have been found on isolated skulls, but I believe this is the first time it has been seen when the atlas is fused. It makes the fact doubly sure to have the free points of the imperfect posterior arches of the atlas and occipital vertebra appear in series one above the other (Fig. 1). This body presented other vertebral irregularities: a supra-sternal bone and (perhaps) a hypochordal brace of the axis (Fig. 5). The last feature is considered in the second division of this communication.

These observations were made on the body of a white man, aet. 50, dissected at the Harvard Medical School, in the season of 1907-08. The skeleton was distinctly pathological, as is often the case with very exceptional vertebral variations. Thus, the two cases which I have reported of 26 præ-sacral vertebræ on one side and 25 on the other were both extremely pathological.³

The calvaria is a fine specimen of hyperostosis manifested on the inner table and especially in the frontal region, where it presents a hummocky surface with a maximum thickness of nearly 18 mm. Towards the posterior inferior parietal angle the thickness is about 12 mm. The buccal surface of the hard palate presents a similar condition (Fig. 4).

The vertebral formula is as follows, omitting any mention of the occipital vertebræ: C. 7, T. 13, L. 5, S. 5, C. 4. The atlas is fused with the occiput, one might say absorbed into it, so far as some parts are concerned. The axis and third vertebra are fused, the fusion dating undoubtedly from early embryonic life (Figs. 2 and 5). On the left the lateral portions of the two vertebræ occupy their normal relations. On the right they are very close together. The laminæ, though fused on the left, retain their distinctness, and the spinous process ends in two knobs, one above the other, each representing the lateral termination of the bifurcated spines of the two vertebræ, while on the right there is but one knob for the

³Dwight, Thomas. Description of the Human Spines Showing Numerical Variation in the Warren Museum of the Harvard Medical School. *Memoirs of the Boston Soc. Nat. History*, V, 237-312. 1901.

two. The spines of the fourth, fifth and sixth cervical vertebræ are bifid. The laminae of the sixth vertebra present on each side a sharp point (Fig. 2, L.) rather less than 1 cm. from the spinous process. That on the left is the larger. The fifth vertebra presents a very small similar projection on the left side only. The bodies of the sixth and seventh cervical and first thoracic vertebræ are fused through prominent exostoses. This is evidently the result of a pathological process, and is accompanied with distortion of this region, the details of which do not seem to the purpose. There are several projections on the ventral aspect of the bodies of the vertebræ in the thoracic region which would ultimately have led to fusion, if they have not already done so, and one on the second lumbar vertebra. Apart from this last feature, the lumbar vertebræ are normal, though the relative spread of their transverse processes is not that of a normal lumbar region. This is owing to the transitional character of the twentieth vertebra, which has been reckoned a thirteenth thoracic. The change in direction of the articular processes occurs below the twelfth thoracic. The costal elements of the twentieth vertebra are free, but insignificant. The right one measures 2.5 cm., the left one 3.3 cm. It is really a matter of taste whether we say that there are thirteen thoracic vertebræ and five lumbar, or twelve thoracic and six lumbar. The twelfth rib measures 13.5 cm. on the right and 14 cm. on the left. There are seven sternal ribs on both sides. On the left the cartilage of the eleventh joins that of the tenth—it probably did not do so on the right. The twenty-sixth vertebra (first sacral) is the *fulcralis*, i. e., the most important one in supporting the sacrum. The third sacral vertebra presents a sudden change in the curve (Hermann von Meyer's *conjugata vera*). The first coccygeal is fused with the sacrum. Thus, except in the last detail, the sacrum is perfectly normal, in spite of the increased number of vertebræ above it. The ensiform cartilage, ossified and fused with the body, is bifid below. The most remarkable feature of the sternum is a knob at the top of the posterior surface of the left half, at the median end of the clavicular notch. It is 6 mm. in height, tolerably clearly marked off, and suggests very strongly a *supra-sternal* bone fused with the manubrium. On the

right the sternum is prolonged upward perhaps a little more than usual, but presents no corresponding structure.

The Occipital Region. The anterior arch and lateral masses of the atlas are well developed, but it is so closely fused with the occiput that there is no sign of any occipital condyles. There is a small interval between the anterior arch and the occiput and on either side of this a deep groove above the atlas. The height through the region of the articular processes is about 2 cm. on the right and 1.5 cm. on the left. Seen from the intracranial side the fusion is very complete. The left posterior arch is, in the main, well developed, quite free, ending in a point some 5 mm. from the median line (Fig. 4). This piece, which is now separate, was in life connected by cartilage to the atlas just external to the inferior articular process. The left vertebral artery grooved its superior surface. The representative of the right posterior arch of the atlas is a thin sliver of bone, the point of which had been broken off (Figs. 1, 3, 4). It was less than 15 mm. in length when measured and probably never was more than 2 or 3 mm. longer. This was separated by a mere crack from the base of the skull at the border of the foramen magnum. The vertebral artery, smaller than the left one, judging from the size of the foramen in the axis, must have passed below this rudimentary arch. The lateral parts of the atlas differ very much on the two sides (Fig. 3). On the left, the costal element of the atlas is wanting, so that the transverse foramen is completely open in front, except for a very slight hook projecting from the median side. The transverse process is strong, and ends in a knob which rests against the vaginal process of the temporal. On the right the lateral mass is inextricably mixed with the occiput. The transverse process is short and indistinct till near its end, which projects strongly backward; but a projection from near the end runs somewhat forward and is assimilated into an ill-marked paramastoid process. The groove already mentioned, anterior to the foramen magnum at the junction of atlas and occiput, has on the right a deeper part, which extends from the anterior condyloid foramen laterally to the entrance to a canal between the transverse process and the skull, which runs antero-posteriorly. (It is unlikely that there was an suboccipital nerve on the right.)

There is an unquestionable manifestation of the posterior arch of an occipital vertebra on the right, and a less distinct one on the left. The right arch forms the boundary of the foramen magnum, but some 3 or 4 mm. before reaching the median line it ends in a point, which is separated from the bone above it by a sharp cleft some 3 mm. deep. This is seen most strikingly on the inner aspect (Fig. 1), but is clear also on the outside (Figs. 3 and 4).

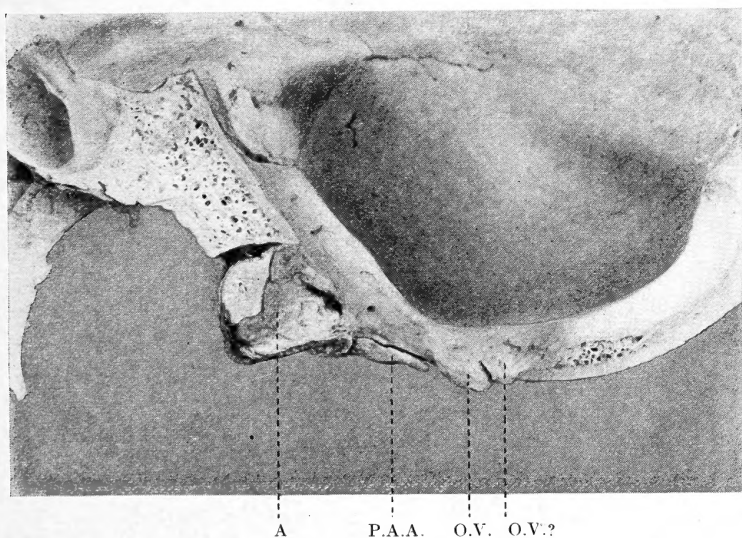


FIG. 1.

A., Atlas. O.V., Manifestation of occipital vertebra. P.A.A., Posterior arch of atlas.

On the right, close to the middle line, and nearer to it than the end of the occipital vertebra above described, there is a small knob which might be held to indicate the termination of another occipital vertebra above it (O. V. (?)). On the lower surface of the left posterior border of the foramen magnum there is a very fair manifestation of the arch of an occipital vertebra, marked off by a groove. It ends rather vaguely some 2 or 3 mm. from the median line (Figs. 3 and 4, O. V.).

The right anterior condyloid foramen is small. On the left it is subdivided into a larger lower and a smaller upper division by a tongue of bone projecting forward from behind and reaching the anterior border. This foramen opens into a groove, already alluded to, between the front of the atlas and the occiput. From the region of the condyle for some distance forward the borders of the occipital bone grow downward so as to shut out the atlas from forming a part of the wall of the spinal canal, and placing it in the main in front of the occiput instead of below it. This is particularly marked on the left. Fig. 3 shows a deep vertical cleft between these bones on the interior surface.

Certain peculiarities are to be noted in the region of the odontoid, which is very long, measuring 19 mm. on the posterior surface, from the lower border of the facet for the transverse ligament to the top. The superior part of the odontoid (nearly one-half) is in the same vertical plane as the anterior surface, but does not reach back to the posterior one. Seen from behind this upper part is a roughened irregular piece of bone, giving a suggestion of an additional element (Fig. 2). A noteworthy point is the difference of position of the anterior and the posterior articular facets of the odontoid. In fact, the highest part of the posterior one does not extend above the level of the middle of the anterior one, which latter reaches to the very top of the odontoid. This is shown in Figs. 2 and 5. The superior articular facets of the axis slant perhaps a little more steeply than usual downward and outward, and the pedicles of the axis decline very steeply behind them. All this would imply that the head must have been carried with the chin high. When we consider the fusion, in some cases congenital and in others pathological, of so many of the cervical vertebrae, it would seem that the power of nodding must have been nearly abolished. Presumably the joints above the axis allowed a great deal of irregular motion.

Besides these manifestations of an occipital vertebra in the region of the foramen magnum, there is on the left side an apparent manifestation of one seen from the front, made by modifications of the anterior border of the occipital bone, which is developed into a horizontal shelf where it bounds the jugular foramen, and, continued

forward, forms the line marking off the groove above the anterior arch of the atlas. This manifestation is much less clear on the right.

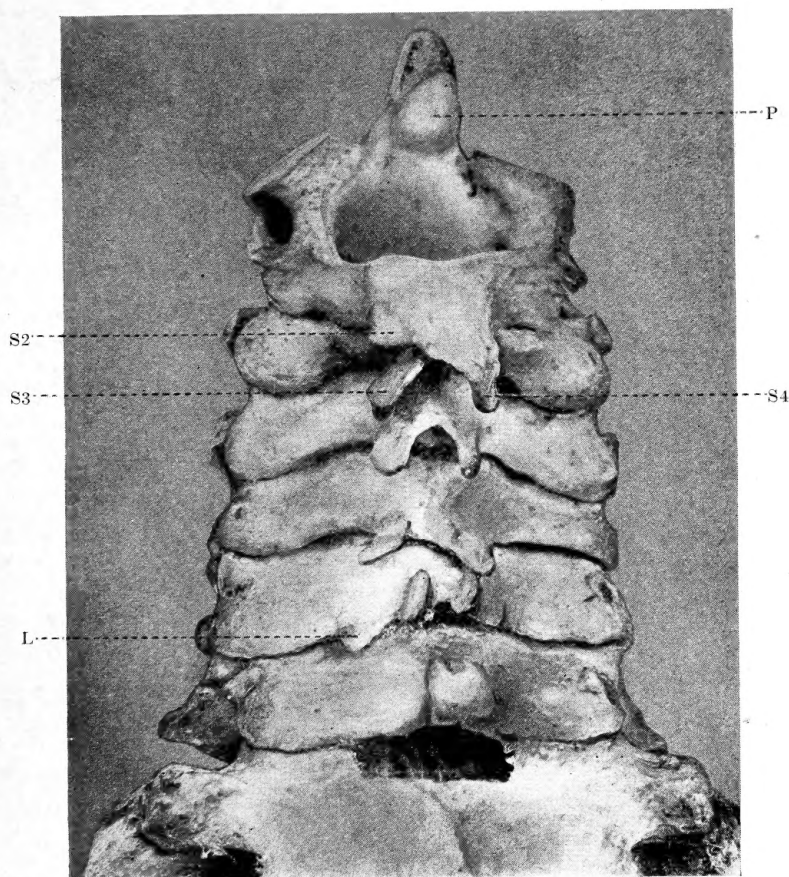


FIG. 2.

L., Point on left lamina of 6th vertebra.

P., Posterior articular facet. S2, Left lateral knob of spine of 2d vertebra. S3, Left lateral knob of spine of 3d vertebra. S4, Right knob resulting from the fusion of the right lateral knobs of the 2d and 3d vertebrae.

On the latter side a delicate process from the border of the occipital divides the exit of the venous canal from the nervous one (Fig. 3, J. F.).

This spine presents also a possible hypochordal brace which is considered in the second part of this paper.

The following facts are to be noted in this case. The presacral vertebrae are increased by a transitional one between the thorax and

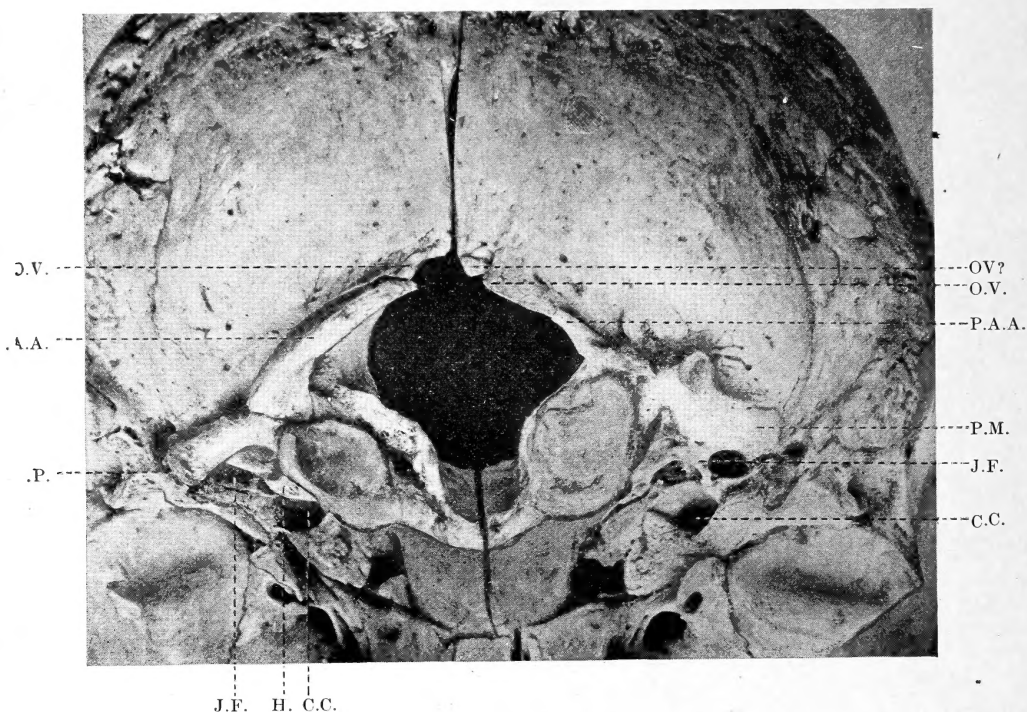


FIG. 3.

C.C., Carotid canal. J.F., Jugular foramen,—under the leader is the spicule dividing it. O.V., Manifestation of occipital vertebra. P.A.A., Posterior arch of atlas. P.M., Paramastoid processes. H., Hook by transverse foramen of atlas. T.P., Left transverse process of atlas resting on vaginal process of temporal.

loins, bearing short movable costal elements. The ribs on the vertebra above it are longer than is usual for last ribs. The second and third vertebrae are fused, the fusion of the arches being more intimate on the right. The atlas is fused much more intimately with the occiput on the right, and the right arch is much less devel-

oped; yet the manifestation of the occipital vertebra, as shown by its free point, is more advanced on the same side. On the right, also, there is the hint of the presence of the point of the arch of still another occipital vertebra. The suggestion of the antero-lateral part of an occipital vertebra is more distinct on the left.

It is much to be regretted that in so few cases of variations about the foramen magnum do we have an account of the entire column. Smith⁴ remarks that "true assimilation of the atlas is rarely, if ever, an isolated anomaly of the cranio-vertebral axis." There can be no doubt as to the correctness of this statement. In support of it Smith points out that the cases of Morgagni, Schiffner and Lambl had also fusion of the axis and the third vertebra; that in two other cases there were cervical ribs; and that a case of his had beside fusion of the axis and third vertebra, a cervical rib and other striking anomalies. To these I would add that among the spines in the Warren Museum showing numerical variation, there are three complete ones with fusion of the atlas and occiput, of which one must be discarded because the fusion is to be considered pathological, and one specimen in which eight vertebræ are preserved. The first (spine 561) has an extra vertebra at the junction of the back and loins, with small free costal elements, while the ribs of the twelfth thoracic are very long. The twenty-fifth vertebra is more or less sacralized on both sides. The next (spine 24) is very normal, only the arch of the last lumbar is distinct and there are certain distinct epiphyses (?) on the caudal side of some of the lumbar articular processes. I have excluded spine D-7 for the reason given. It has only four lumbar vertebræ. The specimen which consists of the neck and the top of the thorax has suffered the loss of the left transverse process of the atlas, probably by accident. On the right the costal element is wanting. Presumably it was free and was lost. Just the same may be said of the right costal element of the seventh. The label states that the vertebral formula is believed to have been normal. It may be repeated that the spine which is described in this paper has an

⁴Smith, G. Elliot. The Significance of Fusion of the Atlas to the Occipital Bone, and Manifestation of Occipital Vertebrae. *British Med. Journ.*, 1908, 594-596.

extra vertebra at the junction of back and loins and fusion of the axis and third, which last feature seems remarkably common in these cases.

We have known for centuries that the atlas may be assimilated more or less completely with the occiput, and for a few years we have accepted the manifestation of an occipital vertebra, usually an inseparable part of the occipital bone. The most perfect observation is that recorded by v. Schumacher,⁵ who described several pieces of a fairly developed vertebra between the atlas and occiput, without bony connection with either. Recently we have had discussions as to whether certain "manifestations" on the bases of isolated skulls were to be considered as belonging to one region or to the other. Even without the light that is thrown on such peculiarities when the spine is present, we must recognize that the case is the same as at other transitional parts of the spinal column. A twenty-fifth vertebra may be a sacral vertebra or a lumbar vertebra, or a cross between the two. It may even be both at once in its two halves. Similar observations may be made at the two ends of the thorax. It is idle to discuss which vertebra a particular vertebra *is*. All we can say is which one it is like. I agree fully with Bateson that we must not treat the members of such a series as individuals. The details of their structure vary according to circumstances. Many years ago Topinard discussed at length which vertebra was wanting in a spine in which there were only eleven thoracic ones. We now know better; but it would seem that in discussing the occipital region we are slow to apply the principles we follow elsewhere.

The great importance of the present specimen is that it is one of the few undoubted cases of assimilation of the atlas and occiput, with manifestation of an occipital vertebra. Perhaps it is the only one. What is most remarkable is that both these processes have made the greatest progress on the same side. The cases of Zoja and Swjetschnikow each show connection between the skull and the spine by means of paramastoid processes from the skull and

⁵Schumacher, Siegmund v. Ein Beitrag zur Frage der Manifestation des Occipitalwirbels. Anat. Anz., XXXI, 1907, 145-159.

anomalous upgrowths to meet them from the transverse processes of the atlas. In the latter's case there is a very slight ossification between the bones at one condyle, which probably is pathological. Now in both these cases the posterior arch of the atlas is apparently both free and well developed. Hence they appear to me to belong to a different class from those in which the body and posterior

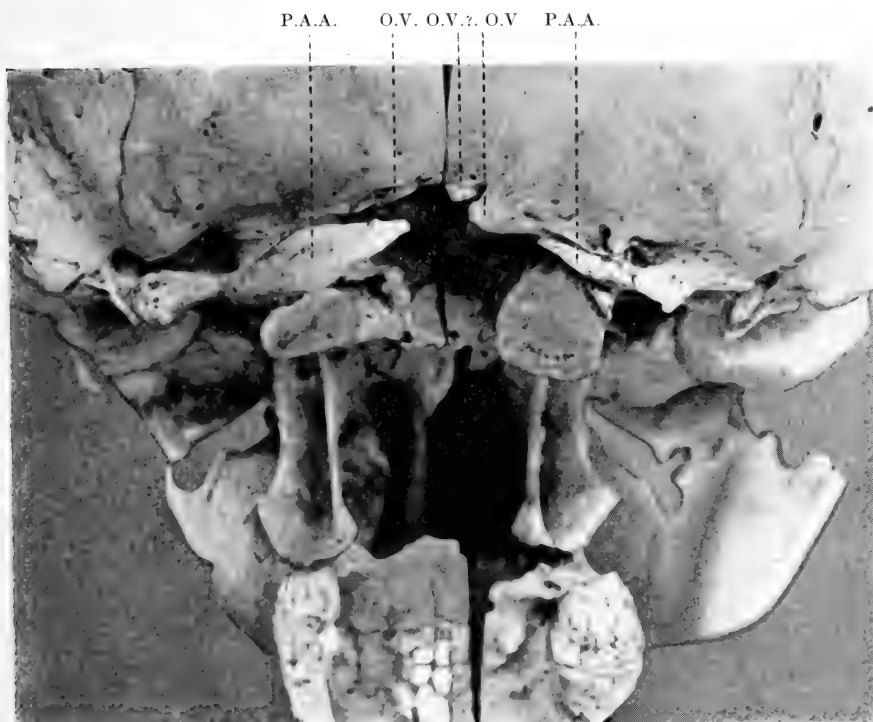


FIG. 4.

P.A.A., Posterior arch of atlas. O.V., Manifestation of occipital vertebra.

arch of the atlas are more or less assimilated with the skull. I regret that Swjetschnikow does not give a figure of his specimen, but he tells us that it is "*demjenigen von Zoja äusserst ähnlich.*" Although the use of color by the Russian anatomist on Zoja's figure is hardly justifiable, as appealing too much to the imagination, it is not to be denied that the tubercle on the anterior border of the

foramen magnum points distinctly to the manifestation of an occipital vertebra of which other parts are indicated. The occipital vertebra must be admitted in these cases; but there is no real assimilation of the atlas and occiput.

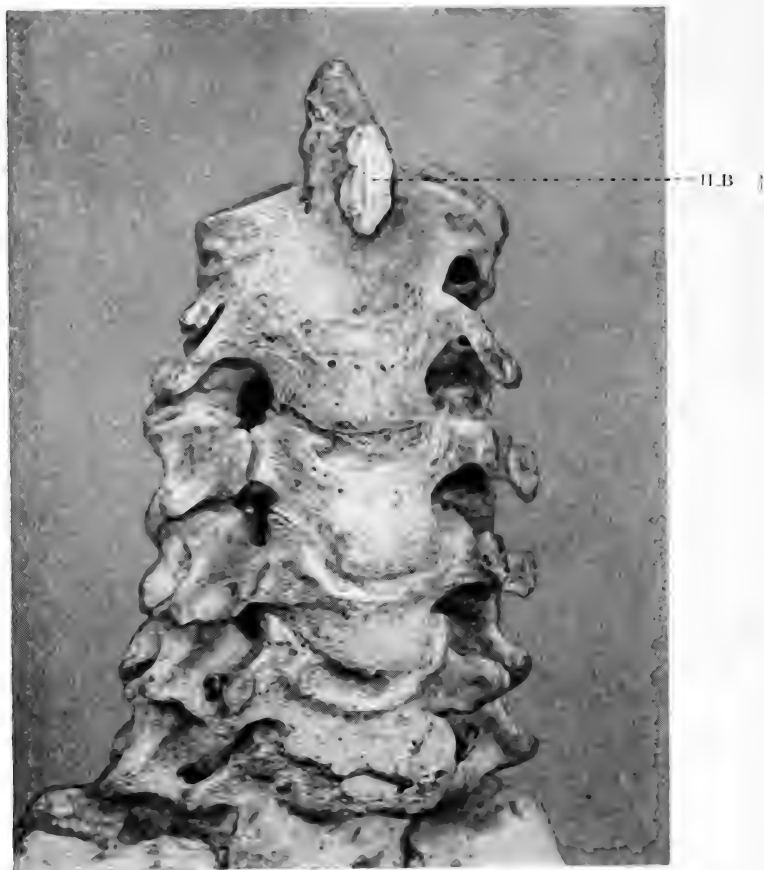


FIG. 5.

H.B., Hypochordal brace.

The present specimen shows far more conclusively the presence in the same body and most markedly on the same side) of two distinctly antagonistic processes, according to the popular theory which would have the one a return to the past and the other a step toward

the future. It is therefore one more piece of evidence for the conservative theory of variation around a mean.

II.

It remains to speak of the *hypochordal brace* (Fig. 5), if indeed that be its morphological significance. It is a stout ossification close on 15 mm. long, with the greatest breadth of some 7 mm. situated free on the front of the axis, its upper part somewhat overlapping the lower border of the anterior articular surface of the odontoid. The anterior arch of the atlas presents a kind of a facet looking downward and forward, which presumably locked with its upper part.

As to the significance of this element, it may be said in favor of its being nothing but an accidental ossification that the body was a distinctly pathological one, showing in many places a tendency to the proliferation of bone. This, in fact, is not to be denied. Nevertheless, the anterior surface of this ossicle has what one may call a "finished" appearance. Whether the fact of its upper dorsal surface being so shaped as to enable it to "lock" with the anterior arch of the atlas is of importance, is a question more easily asked than answered. The fact, however, that an ossification is occasionally found at this precise point speaks strongly for its having a morphological significance. Yet if it be an hypochordal brace, it can be only that of the axis, and embryology leaves one in doubt whether this explanation is legitimate. There is indeed such a cartilaginous *anlage*, but according to Bardeen it is very transient. This spine is so abnormal, showing so many irregularities that must have occurred at a very early period, that it seems favorable soil for such an unexpected growth; but I have recently seen another instance of this ossification, though a smaller one, in a spine which, if not quite normal, was not remarkable.

Just before revising the proof of this paper I received the Anatomischer Anzeiger of May 5, 1909, containing Smith's case of fusion of atlas and occiput with the manifestation of an occipital vertebra.





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